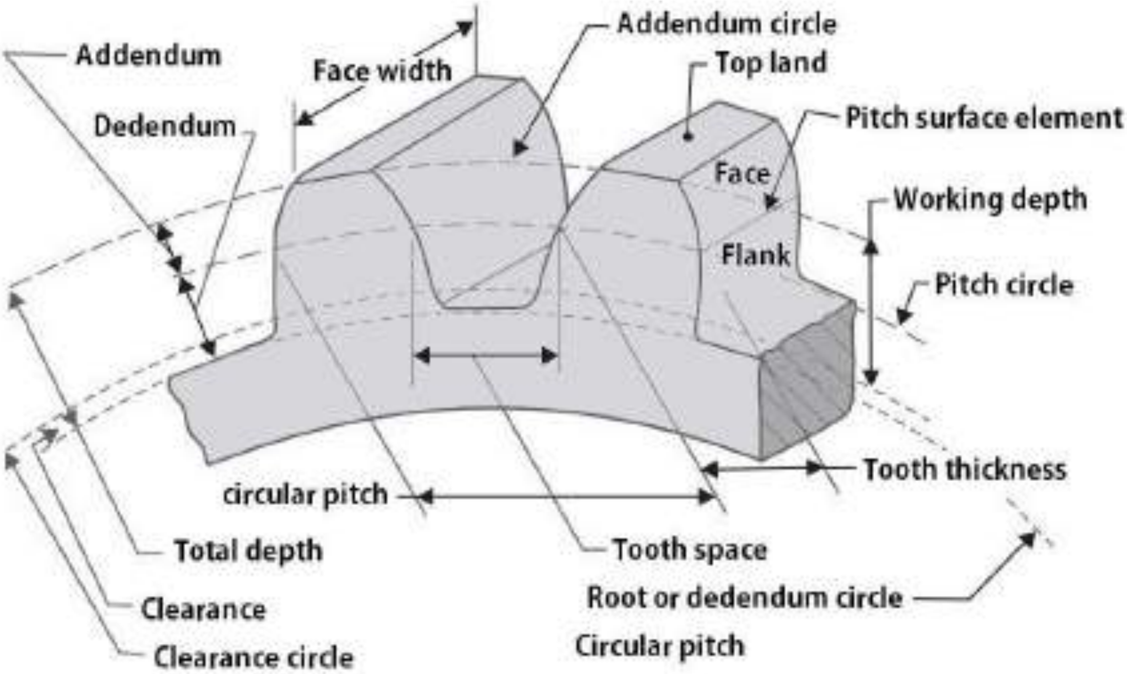
Worm Gear



(1) **Pinion:** A pinion is smaller of the two mating gears.

(2) **Gear:** A gear is larger of the two mating gears.

(3) **Velocity Ratio (*i*):** Velocity ratio is the ratio of angular velocity of the driving gear to the angular velocity of the driven gear. It is also called the speed ratio.

(4) **Transmission Ratio (i'):** The transmission ratio (i') is the ratio of the angular speed of the first driving gear to the angular speed of the last driven gear in a gear train.

(5) **Pitch Surface:** The pitch surfaces of the gears are imaginary planes, cylinders or cones that roll together without slipping.

(6) **Pitch Circle:** The pitch circle is the curve of intersection of the pitch surface of revolution and the plane of rotation. It is an imaginary circle that rolls without slipping with the pitch circle of a mating gear. The pitch circles of a pair of mating gears are tangent to each other.

(7) **Pitch Circle Diameter:** The pitch circle diameter is the diameter of pitch circle. The size of the gear is usually specified by pitch circle diameter. It is also called *pitch diameter*. The pitch circle diameter is denoted by d'.

(8) **Pitch Point:** The pitch point is a point on line of centers of two gears at which two pitch circles of mating gears are tangent to each other.

(9) **Top Land:** The top land is the surface of the top of the gear tooth.

(10) **Bottom Land:** The bottom land is the surface of the gear between the flanks of adjacent teeth.

(12) **Base Circle:** The base circle is an imaginary circle from which the involute curve of the tooth profile is generated. The base circles of two mating gears are tangent to the pressure line.

(13) **Addendum Circle:** The addendum circle is an imaginary circle that borders the tops of gear teeth in the cross-section.

(14) **Addendum (h_a):** The addendum (ha) is the radial distance between pitch and the addendum circles. Addendum indicates the height of tooth above the pitch circle.

(15) **Dedendum Circle:** The dedendum circle is an imaginary circle that borders the bottom of spaces between teeth in the cross-section. It is also called *root* circle.

(16) **Dedendum (h_f):** The dedendum (h_f) is the radial distance between pitch and the dedendum circles. The dedendum indicates the depth of the tooth below the pitch circle.

(17) **Clearance (c):** The clearance is the amount by which the dedendum of a given gear exceeds the addendum of its mating tooth.

(18) **Face of Tooth:** The surface of the gear tooth between the pitch cylinder and the addendum cylinder is called face of tooth.

(19) **Flank of Tooth:** The surface of the gear tooth between the pitch cylinder and the root cylinder is called flank of tooth.

(20) **Face Width (*b*):** Face width is width of the tooth measured parallel to the axis.

(21) **Fillet Radius:** The radius that connects the root circle to the profile of the tooth is called fillet radius.

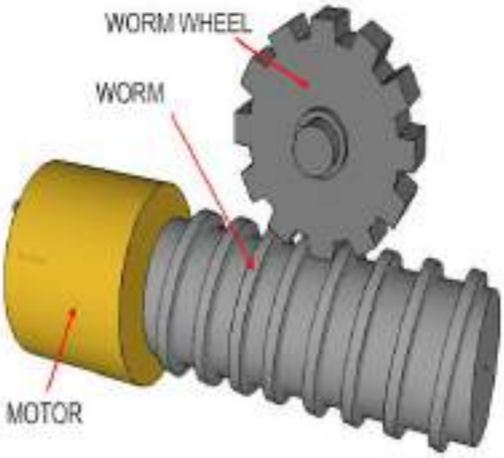
(22) **Circular Tooth Thickness:** The length of the arc on pitch circle subtending a single gear tooth is called circular tooth thickness. Theoretically, circular tooth thickness is half of circular pitch.

(23) **Tooth Space:** The width of the space between two adjacent teeth measured along the pitch circle is called the tooth space. Theoretically, tooth space is equal to circular tooth thickness or half of circular pitch.

(24) **Working Depth (h_k):** The working depth is the depth of engagement of two gear teeth, that is, the sum of their addendums.

(25) **Whole Depth (h):** The whole depth is the total depth of the tooth space, that is, the sum of addendum and dedendum. Whole depth is also equal to working depth plus clearance.

(26) C...



The worm gear drives are used to transmit power between two non-intersecting shafts, which are, in general, at right angles to each other. The worm gear drive consists of a worm and a worm wheel. The worm is a threaded screw, while the worm wheel is a toothed gear. The teeth on the worm

ADVANTAGES

(i) The most important characteristic of worm gear drives is their high speed reduction. A speed reduction as high as 100:1 can be obtained with a single pair of worm gears.

(ii) The worm gear drives are compact with small overall dimensions, compared with equivalent spur or helical gear drives having same speed reduction.

(iii) The operation is smooth and silent.

(iv) Provision can be made for self-locking operation, where the motion is transmitted only from the worm to the worm wheel. This is advantageous in applications like cranes and lifting devices.

Drawbacks

The drawbacks of the worm gear drives are as follows:

(i) The efficiency is low compared with other types of gear drives.

(ii) The worm wheel, in general, is made of phosphor bronze, which increases the cost.

(iii) Considerable amount of heat is generated in worm gear drives, which is required to be dissipated by a lubricating oil to the housing walls and finally to the surroundings.

(iv) The power transmitting capacity is low. Worm gear drives are used for up to 100 kW power transmission.

Types of worms

1. Straight face worm gear
2. Hobbed straight face worm gear
3. Concave face worm gear

The straight face worm gear is like a helical gear in which the straight teeth are cut with a form cutter. Since it has only point contact with the worm thread, therefore it is used for light service.

The hobbed straight face worm gear is also used for light service but its teeth are cut with a hob, after which the outer surface is turned.

The concave face worm gear is the accepted standard form and is used for all heavy service and general industrial uses. The teeth of this gear are cut with a hob of the same pitch diameter as the mating worm to increase the contact area.

2 Introduction

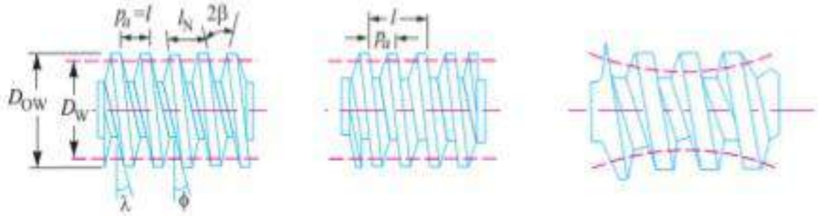
The worm gears are widely used for transmitting power at high velocity ratios between non-intersecting shafts that are generally, but not necessarily, at right angles. It can give velocity ratios as high as 300 : 1 or more in a single step in a minimum of space, but it has a lower efficiency.

3 Types of Worms

The following are the two types of worms:

1. Cylindrical or straight worm, and
2. Cone or double enveloping worm.

The ***cylindrical*** or ***straight worm,*** as shown in Fig. 1 (a), is most commonly used. The shape of the thread is involute helicoid of pressure angle $14\frac{1}{2}^o$ for single and double threaded worms and 20^o for triple and quadruple threaded worms. The worm threads are cut by a straight sided milling cutter having its diameter not less than the outside diameter of worm or greater than 1.25 times the outside diameter of worm.
The ***cone*** or ***double enveloping worm,*** as shown in Fig. 1 (b), is used to some extent, but it requires extremely accurate alignment.



Single threaded. Double threaded.

(*a*) Cylindrical or straight worm. (*b*) Cone or double enveloping worm.

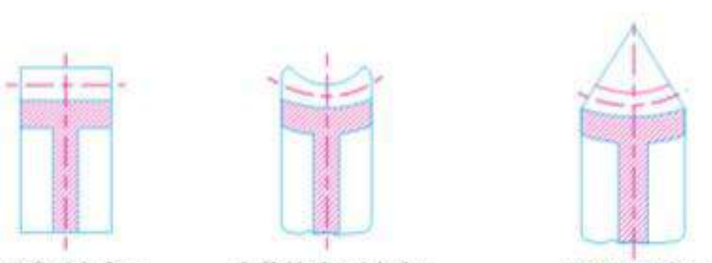
Figure 1: Types of worms.

4 Types of Worm Gears

The following three types of worm gears are important from the subject point of view:

1. Straight face worm gear, as shown in Fig. 2 (a),
2. Hobbed straight face worm gear, as shown in Fig. 2 (b), and
3. Concave face worm gear, as shown in Fig. 2 (c).

The ***straight face worm gear*** is like a helical gear in which the straight teeth are cut with a form cutter. Since it has only point contact with the worm thread, therefore it is used for light service.
The ***hobbed straight face worm gear*** is also used for light service but its teeth are cut with a hob, after which the outer surface is turned.
The ***concave face worm gear*** is the accepted standard form and is used for all heavy service and general industrial uses. The teeth of this gear are cut with a hob of the same pitch diameter as the mating worm to increase the contact area.



(*a*) Straight face. (*b*) Hobbed straight face. (*c*) Concave face.

Figure 2: Types of worms gears.

20.2 TERMINOLOGY OF WORM GEARS

A pair of worm gears is specified and designated by four quantities in the following manner,

$$z_1/z_2/q/m$$

where,

z_1 = number of starts on the worm

z_2 = number of teeth on the wormwheel

q = diametral quotient

m = module (mm)

The diametral quotient is given by,

$$q = \frac{d_1}{m} \qquad (20.1)$$

where, d_1 is the pitch circle diameter of the worm. A schematic diagram of the worm and worm wheel is shown in Fig. 20.1 (a). d_1 and d_2 are pitch circle diameters of the worm and the worm wheel respectively. The worm is similar to a screw with multi-start threads. The threads of the worm have an involute helicoid profile. Following terms are used in design of worm gear drives:

1. **Axial Pitch:** The axial pitch (p_x) of the worm is defined as the distance measured from a point on one thread to the corresponding point on the adjacent thread, measured along the axis of the worm.
2. **Lead:** The lead (l) of the worm is defined as the distance that a point on the helical profile will move, when the worm is rotated through one revolution. It is the thread advance in one turn. For single-start threads, the lead is equal to the axial pitch. For double-start threads, the lead is twice the axial pitch and so on. Therefore,

$$l = p_x z_1 \quad (20.2)$$

The recommended number of starts on worm is as follows:

Velocity ratio	Number of starts
20 and above	Single-start
12-36	Double-start
8-12	Triple-start
6-12	Quadruple-start
4-10	Sextuple- start

The pitch circle diameter of the worm wheel is given by,

$$d_2 = m z_2 \quad (20.3)$$

As seen in the figure, the axial pitch of the worm should be equal to the circular pitch of the worm wheel. Therefore,

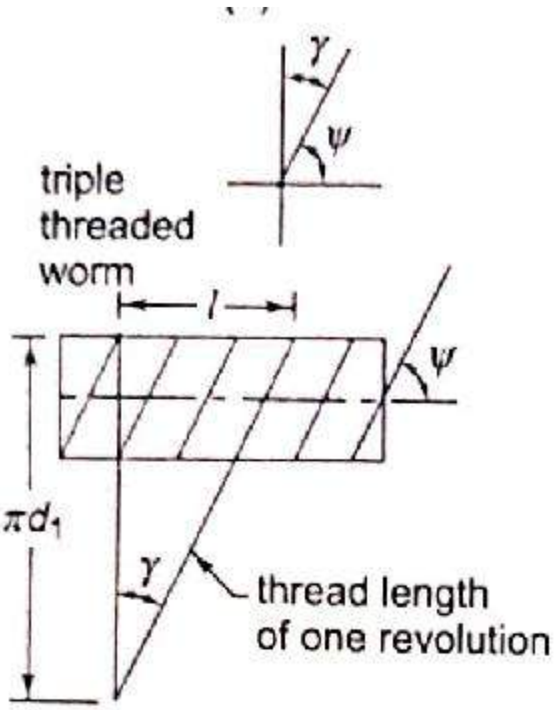
$$p_x = \frac{\pi d_2}{z_2} = \frac{\pi(mz_2)}{(z_2)}$$

or $$p_x = \pi m \tag{20.4}$$

From Eqs (20.2) and (20.4),

$$l = \pi m z_1 \tag{20.5}$$

When one thread of the worm is developed, it becomes the hypotenuse of a triangle, as shown in Fig. 20.1(b). The base of this triangle is equal to the lead of the worm, while the altitude is equal to the circumference of the worm. There are two angles related to this triangle, namely lead angle and helix angle.



(b)

3. **Lead Angle:** The lead angle (γ) is defined as the angle between a tangent to the thread at the pitch diameter and a plane normal to the worm axis. From the triangle in Fig. 20.1(b),

$$\tan \gamma = \frac{l}{\pi d_1} \tag{20.6}$$

From Eqs (20.1) and (20.5),

$$\tan \gamma = \frac{\pi m z_1}{\pi (q m)}$$

or

$$\tan \gamma = \frac{z_1}{q} \tag{20.7}$$

4. **Helix Angle:** The helix angle (ψ) is defined as the angle between a tangent to the thread at the pitch diameter and the axis of worm. The worm helix angle is complement of worm lead angle.

$$\gamma + \psi = \frac{\pi}{2}$$

The helix angle should be limited to 6° per thread. For example, if $\psi = 30°$, then the worm should have at least five threads.

5. **Pressure Angle:** The tooth pressure angle (α) is measured in a plane containing the axis of the worm and it is equal to one-half of the thread angle. It is illustrated in Fig. 20.1 (c). The pressure angle should not be less than 20° for single and double start worms and 25° for triple and multi-start worms.

From Fig. 20.1 (a), the centre distance is given by,

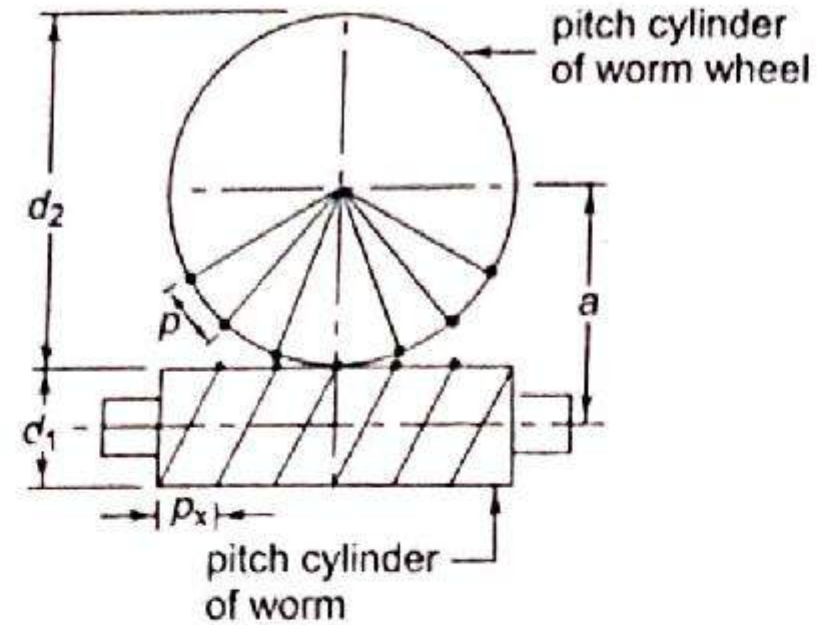
$$a = \frac{1}{2}(d_1 + d_2) \qquad (20.8)$$

where, a is the centre to centre distance. Substituting Eqs. (20.1) and (20.3) in the above expression, we get,

$$a = \frac{1}{2} m (q + z_2) \qquad (20.9)$$

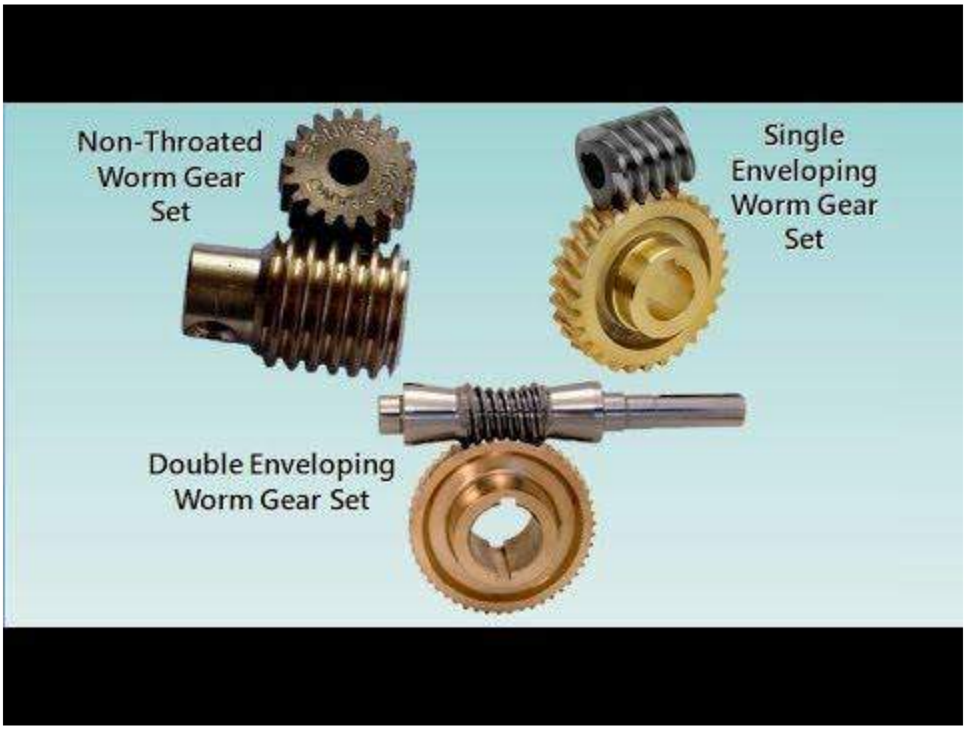
When the worm wheel is rotated through one revolution, the worm will complete z_2 revolution for single start threads. For double start threads, the number of revolutions of the worm will be $(z_2/2)$. The speed ratio (i) is, therefore, given by,

$$i = \frac{z_2}{z_1} \qquad (20.10)$$



There are two classes of worm gear drives in common use, namely single enveloping and double enveloping, as shown in Fig. 20.1 (c) and (d).

(i) **Single Enveloping Worm Gear Drive:** A single enveloping worm gear set is one in which the gear wraps around or partially encloses the worm. This results in line contact between the threads of worm and the teeth of worm wheel. In this case, the worm is also called *cylindrical* or *straight* cylindrical worm. Single enveloping worm gear drive is more widely used.



(ii) **Double Enveloping Worm Gear Drive:** A double enveloping gear set is one in which the gear wraps around the worm and worm also wraps around the gear. This results in area contact between the threads of worm and the teeth of worm wheel. In this case, the worm is also called *hourglass* worm. This drive is also called *cone* gearing.

Double enveloping worm gear drive has following advantages:

(i) The contact pressure between the threads of worm and the teeth of worm wheel is low. This reduces wear.

(ii) The drive occupies less space for a given capacity. Double enveloping worm gear drive needs only about two-third of the space and has about one-third of the weight compared with single enveloping worm gear drive.

The main draw back of double enveloping worm gear drive is requirement of precise alignment. It is much more critical than in case of single enveloping worm gear drive. A small deviation from correct centre distance results in the loss of theoretical area of contact.

THANK YOU.

Question Session

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